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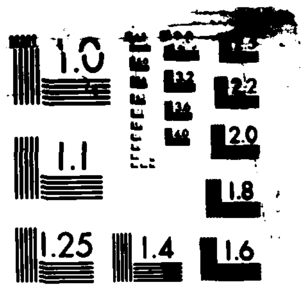


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## TECHNICAL NOTE

## MRL-TN-495

INVESTIGATION OF A PROPELLANT FIRE AT
MULWALA EXPLOSIVES FACTORY, JULY 1984

G. Bajinskis







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ABSTRACT

The cause of a fire in the propellant cutting area of Mulwala Explosives Factory was investigated. Extensive measurements of electrostatic charge generation and dissipation showed that, at the time of the fire, the electrostatic charge on the cut propellant could have been in excess of sixty times that required to ignite the surrounding ether vapour. Subsequent investigations have shown that the use of metal labyrinths in the flow of cut propellant together with conducting collection buckets are successful in reducing the electrostatic energy to below the ignition level.




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POSTAL ADDRESS: Director, Materials Research Laboratories
P.O. Box 50, Ascot Vale, Victoria 3032, Australia

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| G. Bajinskis | Materials Research Laboratories<br>P.O. Box 50,<br>Ascot Vale, Victoria 3032 |


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ABSTRACT

The cause of a fire in the propellant cutting area of Mulwala Explosives Factory was investigated. Extensive measurements of electrostatic charge generation and dissipation showed that, at the time of the fire, the electrostatic charge on the cut propellant could have been in excess of sixty times that required to ignite the surrounding ether vapour. Subsequent investigations have shown that the use of metal labyrinths in the flow of cut propellant together with conducting collection buckets are successful in reducing the electrostatic energy to below the ignition level.


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CONTENTS

# INVESTIGATION OF A PROPELLANT FIRE AT MULWALA EXPLOSIVES FACTORY, JULY 1984

## 1. INTRODUCTION

This report describes an investigation of a fire that occurred at Mulwala Explosives Factory on the 6th July 1984 in the section where double-base propellant is cut. It was reported that an operator placed his arm into a plastic collection bucket to take a routine sample of propellant and experienced an electric shock to his hand. The propellant powder in the bucket then ignited.

As the propellant cutting operation is carried out in an atmosphere of air and ether vapour, it is assumed that the fire was due to the ignition of this ether/air mixture. Thus the criterion for assessing the electrostic hazard involved in the various operations is taken to be whether electrostatic energies involved were sufficient to ignite ether/air mixtures. This ignition energy is well documented [1] to be 200 μJ.

Measurements were made of the accumulation of electrostatic charge on propellant collection buckets and on personnel under a variety of operating conditions. Resistance measurements were made to indicate the suitability of various materials used in propellant handling.

The result of the investigation indicated that the cause of the fire was most likely due to the ignition of ether/air mixture caused by an electrostatic discharge from the surface of the cut propellant to the hand of the operator.

## 2. TEST CONDITIONS

### 2.1 Environment and Propellants

The temperature in the buildings where propellant cutting took place and where the measurements were conducted was between 16°C and 24°C with a relative humidity of between 35% and 55%.

The floor in the vicinity of the cutting machine involved in the fire was of wood pulp composition in a damp condition and contributed very little to the body-to-ground resistance as found in the tests in Section 5. The footwear worn by the operators was factory issue antistatic footwear (see Section 5).

Both single-base (AR 2206) and double-base (102-4) propellants were used in the tests.

### 2.2 Test Equipment

Electrostatic potential measurements were performed with a Rothschild Static Voltmeter and a 3M Static Gun. Resistance measurements were carried out with an Insulation Tester and a Radiometer Megohmeter. Capacitance was measured with an Impedance Bridge.

### 2.3 Propellant Cutting Operation

Extruded propellant cords containing up to 30% ether are drawn into the cutting machine by the feed-rollers. The cords are then cut to length by rotating blades and then discharged through a chute into collection buckets.

## 3. ELECTROSTATIC CHARGING OF PROPELLANT IN BUCKETS

Tests were carried out to investigate the electrostatic charge accumulation effects due to type of collecting bucket, length of propellant cut and the presence of labyrinths in the cut propellant stream.

The potential of the cut propellant was monitored during the cutting operation with an electrostatic voltmeter linked to a probe at the bottom of the bucket. For measurements on fibre and metal buckets the probe was isolated from the base of the bucket with a thin sheet of plastic slightly larger than the probe electrode. The bucket was centrally placed on an earthed metal plate under the flow of cut propellant as shown in Figs. 1 and 2.

The capacitance between the probe and earth when the bucket contained 4 to 5 kg of propellant was measured to be 150 pF.

### 3.1 Bucket Types and Propellant Types

Table 1 gives the peak potential and corresponding energy when 4 kg of cut propellant was collected in buckets made from metal, fibre and plastic as shown in Fig. 3. The plastic buckets, when new, were claimed to be "anti-static".

TABLE 1 - ELECTROSTATIC POTENTIAL AND ENERGY FOR VARIOUS BUCKET TYPES

| Bucket type | Potential (kV) | Energy (C = 150 pF) (μJ) |
|---|---|---|
| Metal | <0.1 | <1 |
| Fibre | <0.1 | <1 |
| Plastic | 13 | 13 000 |

The figure obtained with the plastic bucket is more than sixty times the minimum energy (200 μJ) required to ignite ether/air mixtures[1]. The maximum potential measured was limited by the amount of available propellant. Even higher energies have been reported for similar measurements [2]. The rate of increase of the potential in one trial on the cut propellant is shown in Fig. 4.

It was found that the charge accumulated was essentially independent of the type of propellant (single-base AR 2206 or double-base 102-4) cut.

### 3.2 Variation of Potential with Length of Cut

The length of cut propellant was varied by changing either the cutting disc or the rate of feed of the cutting machine. The charge accumulated on the cut propellant was measured by use of an insulated metal bucket. It was found that the potential developed was independent of the cutting disc used but fell from 13 kV to 9 kV for the fast feed rate which was about three times the feed rate used for the results in Table 1.

### 3.3 Effect of Labyrinths

Experiments were carried out to determine the effectiveness of the various earthed labyrinths shown in Fig. 5 in dissipating electrostatic charge from cut propellant. In these tests, the labyrinths were placed in the cut propellant stream between the cutting blade and the collecting bucket. A metal bucket, isolated from earth and connected to the static voltmeter, was used to collect the propellant.

#### 3.3.1 Labyrinth No. 1

This labyrinth (Fig. 5) was already in use on some machines and tests were conducted with different cutting discs to produce different lengths of cut propellant. The results are given in Table 2.

TABLE 2 - LABYRINTH No. 1

| Disc | Maximum potential without labyrinth (kV) | Maximum potential with labyrinth No. 1 (kV) |
|---|---|---|
| 60 blade | 12 | 0.8 |
| 90 blade | 13 | 3.8 |

#### 3.3.2 Labyrinth Assembly No. 2

Labyrinth assembly No. 2 consisted of labyrinth No. 1 modified by the addition of an aluminium foil-lined chute, 600 mm long, placed directly under the outlet as in Fig. 5. The peak potential on the metal collecting bucket was measured to be 0.2 kV but the propellant tended to pile up.

#### 3.3.3 Labyrinth Assembly No. 3

Labyrinth assembly No. 3 consisted of labyrinth No. 1, a funnel and a cone.

Two cones, one with a high slope (small included angle) and one with a low slope (large included angle), were tried in turn and are shown in Fig. 5. The results are given in Table 3.

TABLE 3 - LABYRINTH ASSEMBLY No. 3, TWO CONES

| Cone type | Maximum potential (kV) |
|---|---|
| Low slope | 0.5 |
| High slope | 1.8 |

The propellant tended to pile up on the low-slope cone.

## 4. OPERATOR BODY POTENTIAL MEASUREMENTS

The potential on the operator was monitored while wearing old shoes and walking near the cutting machine. At no time did the potential rise above 1 V. This is consistant with values reported in [3].

To simulate the extreme case of operator charging, measurements were made while the operator stood on an insulating foam sheet and vigorously brushed one hand against the inside of plastic bucket (No. 5 in Fig. 3). The peak potential obtained was 1 kV and the energy stored for a body to ground capacitance of 95 pF would be 47 µJ. This is less than the 200 µJ required to ignite ether/air mixtures [1].

## 5. OPERATOR BODY-TO-GROUND RESISTANCE MEASUREMENTS

The body-to-ground resistance of an operator was measured over a period of two days while wearing the old shoes in use at the time of the fire and also while wearing a new pair. These measurements were taken while standing on the floor near the cutting machine and also while standing on a metal plate. The operator concerned in both the fire and these tests wore special rubber insoles for medical reasons and these were removed for some of the tests. The results are given in Table 4.

TABLE 4 - BODY-GROUND RESISTANCE

| Footwear | Insoles | Body-to-ground resistance (Ω) | |
|---|---|---|---|
| | | On Floor | On Metal Plate |
| Old | Yes | $4 \times 10^6$ to $1.7 \times 10^7$ | $5 \times 10^6$ |
| Old | No | $1 \times 10^6$ | $5 \times 10^5$ |
| New | Yes | $6 \times 10^5$ to $3 \times 10^6$ | $6 \times 10^5$ to $1.5 \times 10^6$ |
| New | No | no measurement | $1.2 \times 10^6$ |

The values in Table 4 are generally acceptable for "anti-static" footwear.

## 6. TESTS ON BUCKETS

### 6.1 Resistance

Electrical resistance was measured through the base of the bucket, between an electrode 8 cm in diameter placed inside and a metal plate on which the bucket was standing. It was found that the resistance of fibre buckets was between $10^5$ and $10^7$ ohm whereas the plastic buckets, whether used or unused, exhibited resistances of between $10^{12}$ and $10^{14}$ ohm. One of the fibre buckets was placed in an oven and dried at 70°C. The resistance increased from $10^7$ ohm to $10^{11}$ ohm.

### 6.2 Surface Charging of Plastic Buckets

Both used and unused plastic buckets were charged by rubbing with a dry cotton cloth and the resultant surface potential measured with a static gun. The used buckets produced a potential of about 10 kV and sparking was evident when an earthed probe was moved towards the test area of the bucket.

On the other hand, unused buckets produced a potential of only 1 kV but this increased to 3 kV for areas that were rubbed with an ether-soaked rag before charging. As these buckets, when new, were claimed to be 'anti-static' it appears that exposure to ether can reduce their anti-static properties. Further, the unused buckets were slightly sticky to the touch whereas those exposed to ether were not. It was also noticed that the unused buckets were much lighter in colour than the used buckets, as can be seen from Fig. 3. This suggests that an anti-static coating is present when new but is degraded by ether.

## 7. CONCLUSIONS

The electrostatic potential developed on cut propellant when collected in plastic buckets was such that the energy available was in excess of sixty times that required to ignite ether/air mixture. This contrasts with the use of metal or fibre buckets where the electrostatic charge accumulation was negligible.

Measurements on the operator-shoes-floor system and a re-enactment of the operator movements prior to the fire indicated that there would have been insufficient electrostatic charge generated to ignite ether vapour from operator movement alone.

Thus it is concluded that the cause of the fire was most likely due to an electrostatic discharge from the surface of the cut propellant to the hand of the operator as he reached into the bucket to collect a sample.

The use of a metal labyrinth in the flow of cut propellant together with conducting collecting buckets and their associated earthing systems were successful in reducing electrostatic charging to below the level required to ignite ether/air mixture. Resistance and charging tests on metal, fibre and plastic buckets showed that the use of the plastic buckets results in excessive charge accumulation. There was evidence that a coating was present on unused plastic buckets which, although not an effective conductor of electrostatic charge, tended to reduce charging by rubbing. This coating was apparently removed by exposure to ether whereupon significant charging could occur. For these reasons the use of these so-called "anti-static" plastic buckets should be avoided.


## 8. ACKNOWLEDGEMENTS

The valuable assistance of Mr P. Star in performing the measurements is appreciated.

## 9. REFERENCES


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Fig. 1. Electrostatic charging tests on cut propellant in Building 234B. Photograph shows electrical discharging of cut propellant by earthing of meter input on the right of the photograph and the monitoring of surface charge by the operator prior to removal of electrode from the plastic bucket.

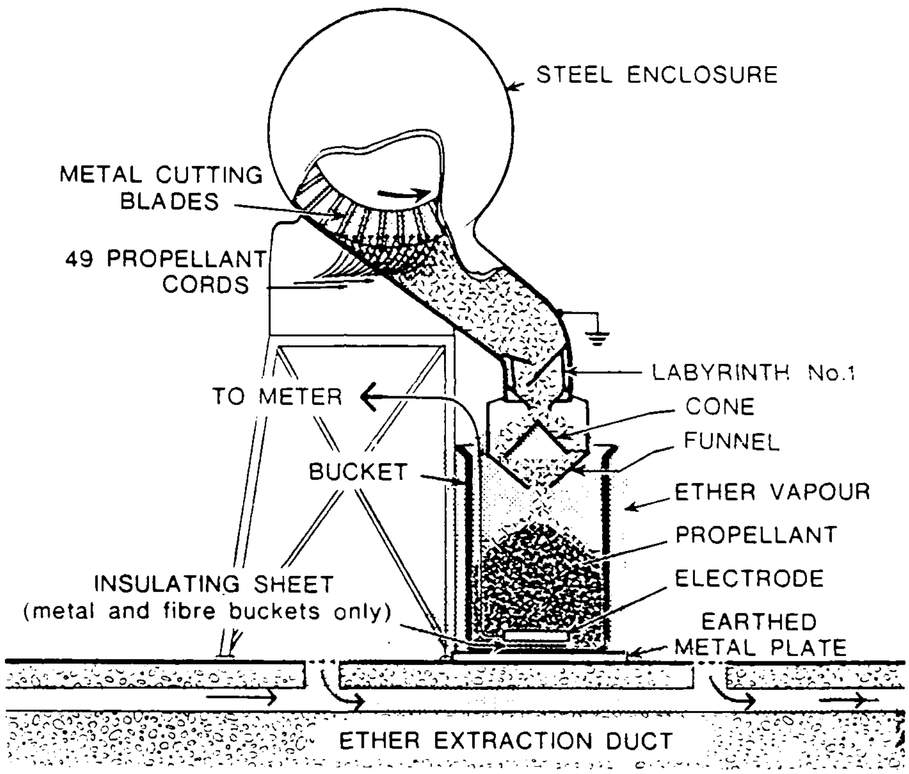


Fig. 2. Sectional view of the cutting machine showing flow of propellant over the labyrinth and cone.

Fig. 3. Buckets and container tested during investigation. From left 1 & 2 fibre, 3 to 5 plastic used, 6-8 plastic unused, 9 to 12 fibre, 13 metal.

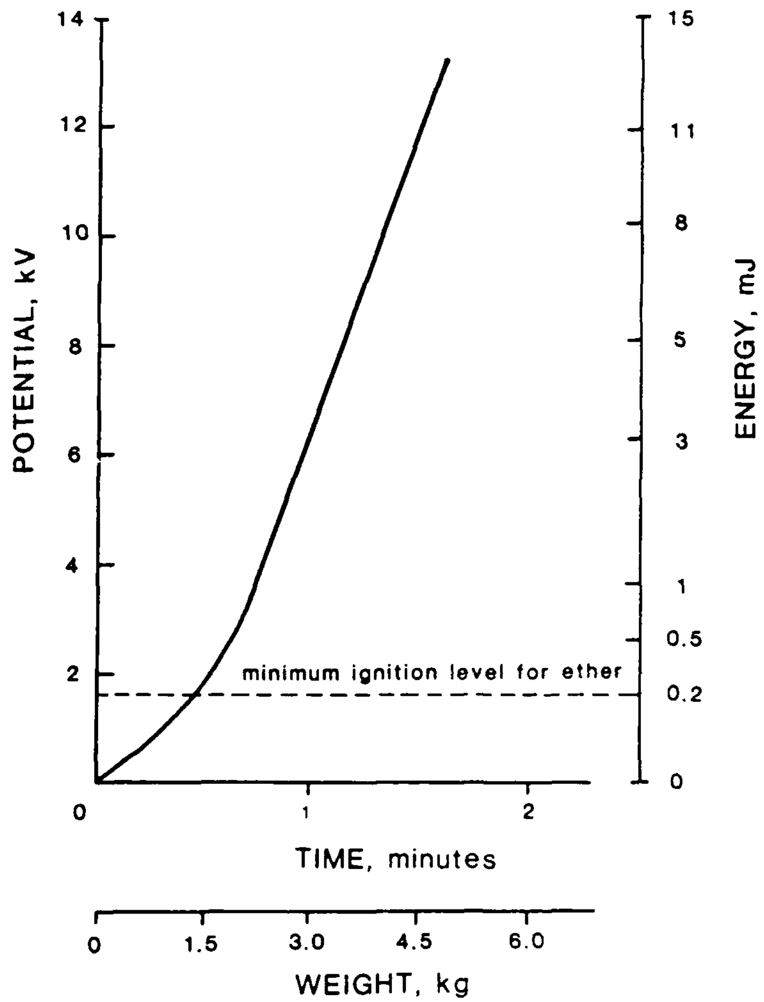


Fig. 4 Electrostatic potential and energy (for C = 150 pF between propellant and earth) of cut propellant against time of cutting and weight of collected propellant. Also shown is the minimum ignition level of ether vapour.

Fig. 5 Evaluation of various charge dissipators. From left in the hands of the operators labyrinth No. 1, a funnel and two aluminium cones with the low slope cone above the high slope cone. The aluminium foil chute is in position under the cutting machine and over the metal bucket.

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